Renewable and Sustainable Energy Reviews 20 (2013) 565–569

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

An overview of Australia's hydropower energy: Status and future prospects

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ARTICLE INFO

Article history:
Received 23 October 2012
Received in revised form
21 December 2012
Accepted 21 December 2012
Available online 18 January 2013

Keywords:
Australia
Hydropower
Hydroelectricity
Sustainable energy

ABSTRACT

Hydropower is the most advanced and mature renewable energy technology and provides some level of electricity generation in many countries worldwide. As hydropower does not consume or pollute the water it uses to generate power, it leaves this vital resource available for other uses. The objective of this article is to identify and analyse issues that are imperative for hydropower energy development in Australia. This study shows opportunities for further hydroelectricity generation in Australia are offered by refurbishment and efficiency improvements at existing hydroelectricity plants, and continued growth of small-scale hydroelectricity plants connected to the grid.

Contents

1. Introduction

Hydropower is the most advanced and mature renewable energy technology and provides some level of electricity generation in more than 160 countries worldwide. Hydropower plants convert potential energy of water into electricity. The water, after generating electrical power, is available for irrigation and other purposes [1].

From 2007 to 2035,world renewable energy use for electricity generation grows by an average of 3.0% per year and the renewable share of world electricity generation increases from 18% in 2007 to 23% in 2035 [2].

Yuksel [3] has discussed the advantages and disadvantages of the hydropower option in details. Hydro is a renewable energy source and has the advantages of low greenhouse gas emissions, low operating costs, and a high ramp rate (quick response to electricity demand) [3–6].

In several countries hydropower is the largest contributor to grid electricity. It is not uncommon in developing countries for a

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1364-0321/$ - see front matter
http://dx.doi.org/10.1016/j.rser.2012.12.026

large dam to be the main generating source. Nevertheless Brazil, Canada, China, Russia and the United States currently produce more than half of the world's hydropower [7–9]. The world's total technically exploitable hydroenergy potential is estimated to be around 16500 TWh per year [10].

Hydroelectricity generation accounted for 2.2% of total primary energy consumption in 2007 (Table 1). World hydroelectricity consumption has grown at an average annual rate of 2% between 2000 and 2007. However, in the Organisation for Economic Cooperation and Development (OECD) countries, hydroelectricity consumption has been declining at an average annual rate of 0.3% [11].

In South America, the highest hydroenergy potential is in Brazil, where it exceeds 2200 TWh per year. In Africa, the Democratic Republic of the Congo has the highest hydroenergy potential, while Norway's potential resources are the highest in Western Europe. Other countries with substantial potential include Canada, Chile, Colombia, Ethiopia, India, Mexico, Paraguay, Tajikistan and the United States [10].

China's hydroenergy resources are the largest of any country. China is estimated to have a theoretical potential of more than 6000 TWh per year, approximately double current world hydroelectricity generation, and economically feasible potential of more than 1750 TWh per year [11].

According to outlook for the world hydroelectricity market In the International Energy Agency (IEA) reference case projections; world hydroelectricity generation is projected to increase to 4680 TWh in 2030, at an average annual rate of 1.8% (Table 2). Hydroelectricity generation is projected to grow in the Organisation for Economic Cooperation and Development (OECD) countries at an average annual rate of 0.7% and in non-OECD countries by an average annual rate of 2.5% [12].

Nevertheless, almost all countries have some hydroenergy potential, Australia's theoretical hydroenergy potential (265 TWh per year) is considered to be relatively small, ranking 27th in the world. High rainfall variability, low average annual rainfall over most of the continent, and high temperatures and evaporation rates limit the availability of surface water resources [10,12].

Table 1
Key hydro statistics (2009) [11,22,25].

	Unit	Australia	OECD countries	World
Primary energy consumption	PJ	43.4	4654	11,084
Share of total	%	0.8	2	2.2
Average annual growth, from 2000	%	−4.2	−0.3	2
Electricity generation				
Electricity output	TWh	12	1293	3078
Share of total	%	4.5	12.2	15.6
Electricity capacity	GW	7.8	366.9	848.5

Table 2
IEA reference case projections for world hydroelectricity generation [26].

	Unit	2009	2030
OECD, countries	TWh	1258	1478
Share of total	%	12.2	11.2
Average annual growth, present—2030	%	–	0.7
Non-OECD countries	TWh	1820	3202
Share of total	%	19.9	15.2
Average annual growth, present—2030	%	–	2.5
World	TWh	3078	4068
Share of total	%	15.6	13.6
Average annual growth, present—2030	%	–	1.8

2. Australia's hydroenergy resources

There is high variability in rainfall, evaporation rates and temperatures between years, resulting in Australia having very limited and variable surface water resources. Of Australia's gross theoretical hydro-energy resource of 265 TWh per year, only around 60 TWh is considered to be technically feasible [11,12,29].

Australia's economically feasible capacity is estimated at 30 TWh per year of which more than 60% has already been harnessed [11,12].

Australia currently has 108 operating hydroelectric power stations with total installed capacity of 7806 MW. These coincide with the areas of highest rainfall and elevation and are mostly in New South Wales (55%) and Tasmania (29%)[13,14]. There are also hydroelectricity schemes in north-east Victoria, Queensland, Western Australia, and a mini-hydroelectricity project in South Australia. Pumped storage accounts for about 1490 MW [12,15].

The hydroelectricity generation system in Tasmania comprises an integrated scheme of 28 power stations, numerous lakes and over 50 large dams. Hydro Tasmania, the owner of the majority of these hydroelectricity plants, supplies both base load and peak power to the National Electricity Market (NEM), firstly to Tasmania and then the Australian network through Basslink, the undersea interconnector which runs under Bass Strait [12,15,16]. Fig. 6 shows the majority of Australian hydropower (water) energy suppliers are located in New South Wales and Tasmania [28].

2.1. Key factors influencing Australia's hydroenergy resources

Most of Australia's best large scale hydroenergy sites have already been developed or, in some cases, are not available for future development because of environmental considerations. There is some potential for additional hydroenergy generation using the major rivers of northern Australia.

Hydroelectricity generation is a low-emissions technology, but future growth will be constrained by water availability and competition for scarce water resources [12].

Many of Australia's hydroelectric power stations are now more than 50 years old and will require refurbishment in the near future. This will involve significant expenditure on infrastructure, including the replacement and repair of equipment. The refurbishment of plants will increase the efficiency and decrease the environmental impacts of hydroelectricity [12].

Refurbishment of the power station at Lake Margaret, Tasmania—one of Australia's oldest hydroelectricity facilities (commissioned in 1914)—commenced in 2008. The main objective of the project was to repair the original wooden pipeline, which had deteriorated [11]. The project involved additional maintenance on the dam, minor upgrade of the machines, as well as replacement of a transformer. This upgrade, completed in late 2009, cost about $14.7 million to gain 8.4 MW of capacity at a capital spend rate of $1.75 million per MW, considerably less than the costs of new plant. Work has commenced on the redevelopment of the Lower Margaret Power Station [11].

2.2. Small scale hydro-developments in Australia

Most hydroelectricity plants installed in Australia in recent years have been mini hydro-schemes. These plants have the advantage of lower water requirements and a smaller environmental impact than larger schemes, especially those with large storage dams.

Although most of Australia's most favourable hydroelectricity sites have been developed, mini-hydroelectricity plants are potentially viable on smaller rivers and streams where large dams are not technically feasible or environmentally acceptable. They can also be retro-fitted to existing water storages. Small hydropower plants, including micro and picoplants, are increasingly seen as a viable source of power because of their lower development costs and water requirements, and their lower environmental footprint. Small scale hydropower plants require special technologies to increase the efficiency of electricity generation and thereby minimise both the operating costs and environmental impacts of hydroelectricity generation. At present mini hydroplants account for only around 2% of installed hydrocapacity. Small scale hydroelectricity plants, including mini (less than 5 MW), micro-(less than 500 kW) and pico-facilities, are still at a relatively early stage of development in Australia, and are expected to be the main source of future growth in hydroelectricity generation. Research, development and demonstration activity is likely to increase the cost competitiveness of small scale hydroschemes in the future.

2.3. Surface water availability

Australia has a high variability of rainfall across the continent. This means that annual inflows to storages can vary by up to 50% and seasonal variations can be extreme.

Water levels in storages across Australia have declined to an average of below 50% of capacity [17]. Cloud seeding has been used in the Snowy Mountains and in Tasmania to augment water supplies.

Climate change models suggest the outlook for southeastern Australia is for drier conditions with reduced rainfall and higher evaporation, and a higher frequency of large storms [18–20]. Reduced precipitation and increased evaporation are projected to intensify by 2030, leading to water security problems in southern and eastern Australia in particular [21]. Competition for water resources will also affect the availability of water for hydroelectricity generation.

Demand for water for urban and agricultural uses is projected to increase. It is likely that these uses for scarce water resources will take precedence over hydroelectricity generation. Generators face increasing demands to balance their needs against the need for greater water security for cities and major inland towns [12].

2.4. Proposed development projects in Australia

Based on Hydropower and Dams [11], there are several current hydroproject developments in Australia:

- A 20 MW hydroplant is currently under construction at the Dartmouth regulating dam in Victoria.
- The next stage of redevelopment of the 8.4 MW Lake Margaret power station in Tasmania has been approved by the board of Hydro Tasmania.
- Hydro Tasmania Consulting has been awarded a contract to supply and construct six mini hydro-plants for Melbourne Water with a total capacity of 7 MW, producing up to 40 GWh per year [12].

3. Australia's hydropower market

Australia has developed much of its large scale hydroenergy potential. Electricity generation from hydro has declined in recent years because of an extended period of drought in eastern Australia, where most hydroelectricity capacity is located.

Hydro-energy is becoming less significant in Australia's fuel mix for electricity generation, as growth in generation capacity is being outpaced by other fuels.

3.1. Status of hydropower within primary energy consumption

As hydroenergy resources are used to produce electricity, which is used in grid or off-grid applications, hydroenergy production is equivalent to hydroenergy consumption. Hydro accounted for 0.8% of Australia's primary energy consumption in 2009–10.

Hydroelectricity generation declined at an average annual rate of 4.2% between 1999–2000 and 2007–08, the result of a prolonged period of drought.

3.2. The role of hydropower within electricity generation

In 2008, Australia's hydroelectricity generation was 12.1 TWh or 4.5% of total electricity generation (Fig. 1). Over the period 1977–78 to 2007–08, hydroelectricity generation has tended to fluctuate, reflecting periods of below or above average rainfall. However, the share of hydro in total electricity generation has steadily declined over this period reflecting the higher growth of alternative forms of electricity generation. Tasmania has always been the largest generator of hydroelectricity in Australia, accounting for 57% of total generation in 2007–08 (Fig. 2). New South Wales is the second largest, accounting for 22% of total electricity generation in 2007–08 (sourced mostly from the Snowy Mountains Hydro-electric Scheme). Victoria, Queensland and Western Australia account for the remainder [12].

3.3. Installed electricity generation capacity

Australia has only 3 hydroelectricity plants with a capacity of 500 MW or more, all of which are located in the Snowy Mountains Hydro-electric Scheme (Figs. 3 and 4). The largest hydroelectricity plant in Australia has a capacity of 1500 MW, which is mid-sized by international standards.

More than 75% of Australia's installed hydroelectricity capacity is contained in 16 hydroelectricity plants with a capacity of 100 MW or more. At the other end of the scale, there are some 60 small and mini-hydroelectricity plants (less than 10 MW capacity) with a combined capacity of just over 150 MW.

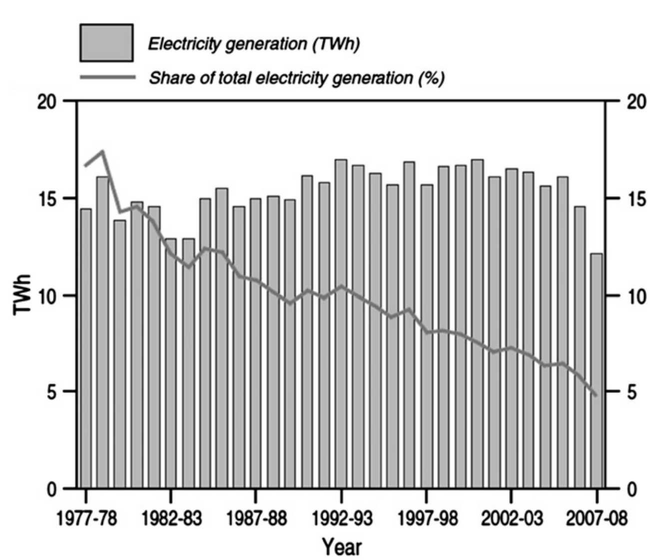

Fig. 1. Australia's hydro-generation and share of total electricity generation (ABARE) [22].

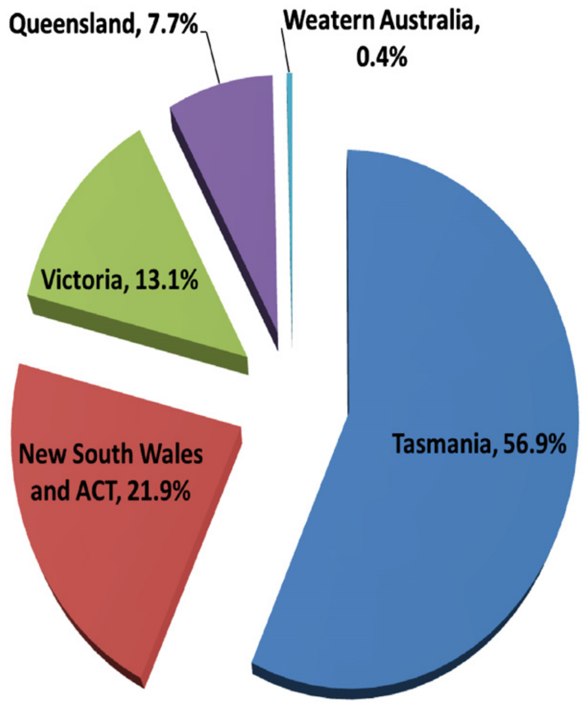

Fig. 2. Australia's hydro-consumption by state, 2007–08. (ABARE) [22].

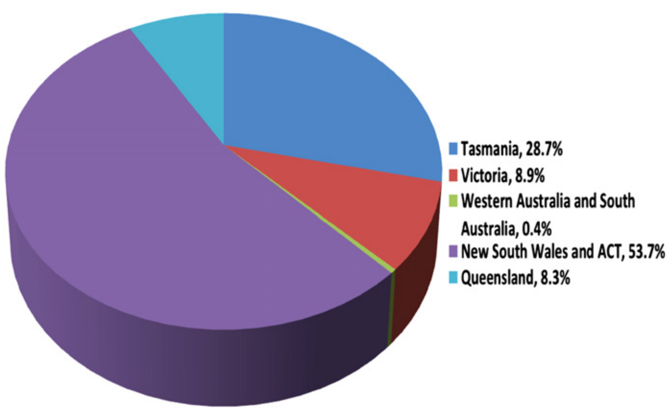

Fig. 3. Installed hydro-capacity by state, Geoscience, Australia [12,27].

However, installed hydroelectricity generation capacity does not directly reflect actual electricity generation. The smaller installed capacity in Tasmania produces more than double the output of the Snowy Mountains Hydro-electric Scheme. Tasmania is the only state that uses hydroelectricity as the main means of electricity generation.

3.4. Outlook for hydroelectricity market in Australia

Hydroelectricity is projected to continue to be an important source of renewable energy in Australia over the outlook period. In ABARE's latest long-term energy projections that include the Australian Government's Renewable Energy Target, a 5% emissions reduction target and other government policies, hydroelectricity generation is projected to increase only slightly between 2007–08 and 2029–30, representing an average annual growth rate of 0.2% [22–24]. In 2029–30, hydro is projected to account for 3.5% of Australia's total electricity generation, and 0.6% of primary energy consumption (Fig. 5). The potential for return of hydroelectricity

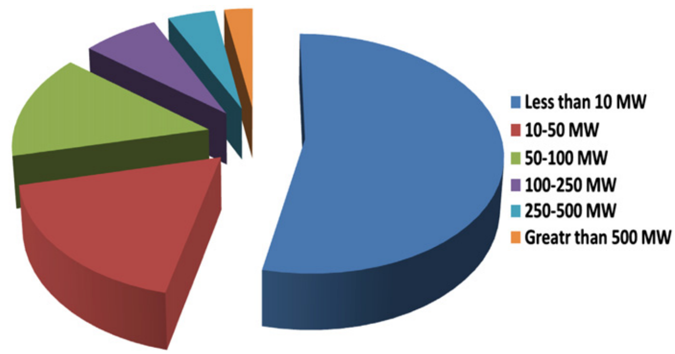

Fig. 4. Installed hydro-capacity by size, [27].

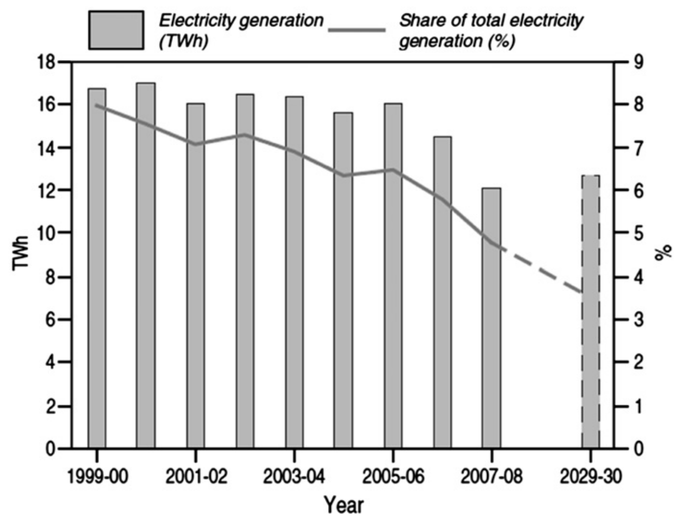

Fig. 5. Australia's hydroelectricity generation to 2029–30 [22–24].

output to pre-2006 levels will be strongly influenced by climate and by water availability [22–24].

3.5. Hydroelectricity supply chain

In Australia virtually all hydroelectricity is produced by stations at water storages created by dams in major river valleys. A number hydroelectricity power stations have facilities to pump water back into higher storage locations during off-peak times for re-use in peak times.

Electricity generated by the water turbines is fed into the electricity grid as base load and peak load electricity and transmitted to its end use market [12].

4. Conclusions

- Hydropower is the most advanced and mature renewable energy technology and provides some level of electricity generation in more than 160 countries worldwide. Its current share in total primary energy consumption is only 2.2% globally and 0.8% in Australia.
- Hydroelectricity is currently Australia's major source of renewable electricity but there is limited potential for future further development.
- Australia is the driest inhabited continent on earth, with over 80% of its landmass receiving an annual average rainfall of less than 600 mm per year and 50% less than 300 mm per year,

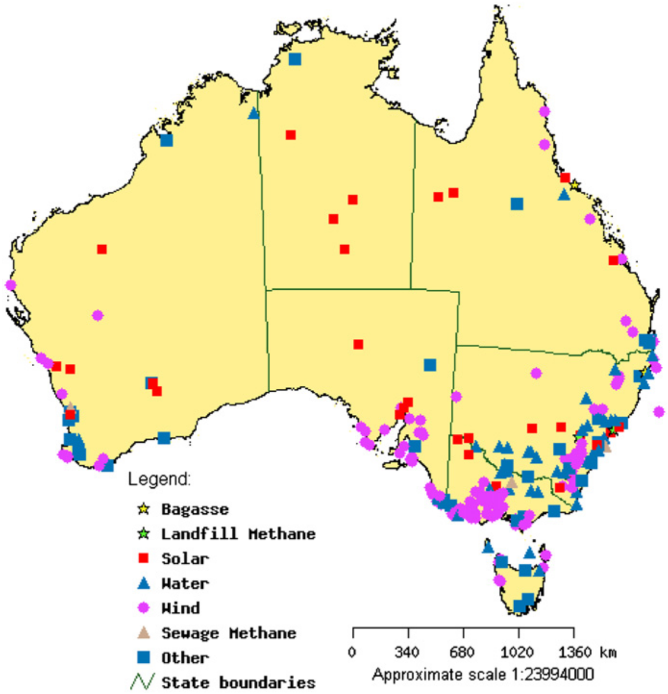

Fig. 6. Location of selected Australian energy resources including hydropower (water) energy [28].

therefore water availability, competition for scarce water resources, and broader environmental factors are key constraints on future growth in Australian hydroelectricity generation.

- Future growth in Australia's hydroelectricity generation will be underpinned by the development of small scale hydroelectricity facilities and efficiency gains from the refurbishment of large scale hydro-plants.
- The share of hydro in Australia's total electricity generation is projected to fall to around 3.5% in 2029–30. Currently Australia's hydroelectricity use represented 0.8% of total primary energy consumption and 4.5% of total electricity generation.
- Hydroelectricity use has declined on average by 4.2% per year between 1999 and 2008, largely as a result of an extended period of drought in Australia.
- Hydro-energy is becoming less significant in Australia's fuel mix for electricity generation, as growth in generation capacity is being outpaced by other fuels.

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